

**ASSESSMENT OF ALUMINA AND MUSCOVITE AS FILLERS
FOR EPOXY SUBSTRATE MATERIAL**

by

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TABLE OF CONTENTS

| | Page |
|------------------------------------|------|
| Acknowledgements | ii |
| Table of Contents | iii |
| List of Tables | ix |
| List of Figures | x |
| List of Proceeding and Publication | xiv |
| Abstrak | xvi |
| Abstract | xvii |

| CHAPTER 1: INTRODUCTION | | Pages |
|-------------------------------------|---|-------|
| 1.1 | Introduction | 1 |
| 1.2 | Problem Statement | 3 |
| 1.3 | Objective of the research | 3 |
| 1.4 | Scope of the research | 4 |
| CHAPTER 2: LITERATURE REVIEW | | |
| 2.1 | Introduction of electronic packaging | 5 |
| | 2.1.1 Flip chip technology | 7 |
| | 2.1.2 Substrate materials | 8 |
| | 2.1.2.1 Ceramic Substrate | 9 |
| | 2.1.2.2 Metal substrate | 10 |
| | 2.1.2.3 Organic substrate | 10 |
| 2.2 | Epoxy resin | 11 |
| 2.3 | Types of particulate fillers using in substrate materials | 17 |
| | 2.3.1. Mica | 17 |
| | 2.3.2 Montmorillonite | 19 |
| | 2.3.3 Fumed silica | 19 |

| | | | |
|--|-------|---|----|
| | 2.3.4 | Aluminium oxide | 20 |
| | 2.3.5 | Aluminum Nitride | 20 |
| | 2.3.6 | Silicon carbide | 21 |
| 2.4 | | Coupling agent | 21 |
| | 2.4.1 | Silane coupling agent | 21 |
| | 2.4.2 | Titanate coupling agent | 24 |
| | 2.4.3 | Surface treatment of alumina by silane coupling agent. | 25 |
| 2.5 | | Surface treatment of mica particles | 25 |
| | 2.5.1 | Ion exchange | 26 |
| | 2.5.2 | Polymer Layered Silicate | 26 |
| | 2.5.3 | Organoclay structure and modeling | 28 |
| CHAPTER 3 : MATERIALS AND METHODOLOGY | | | |
| 3.1 | | Materials | 34 |
| | 3.1.1 | Epoxy resin | 34 |
| | 3.1.2 | Hardener | 35 |
| | 3.1.3 | Fillers | 35 |
| | 3.1.4 | Ethanol | 37 |
| | 3.1.5 | Octadecyl trimethylammonium bromide | 37 |
| | 3.1.5 | (3-Aminopropyl) triethylsilane | 38 |
| | 3.1.6 | Hydrochloric acid (HCl) | 38 |
| | 3.1.7 | Argentum Nitrate, AgNO ₃ | 39 |
| 3.2 | | Treatment of fillers | 39 |
| | 3.2.1 | Alumina | 39 |
| | 3.2.2 | Muscovite | 39 |
| 3.3 | | Sample preparation | 40 |
| 3.4 | | Testing | 41 |
| | 3.4.1 | Characterization of fillers | 41 |
| | | 3.4.1.1 X-Ray Diffraction | 41 |
| | | 3.4.1.2 Fourier Transmission Infra Red (FTIR) | 41 |

| | | |
|--|--|----|
| 3.4.2 | Mechanical properties | 42 |
| 3.4.2.1 | Flexural properties | 42 |
| 3.4.2.2 | Fracture toughness | 43 |
| 3.4.3 | Thermal properties | 45 |
| 3.4.3.1 | Thermo gravimetric analysis (TGA) | 45 |
| 3.4.3.2 | Dynamical Mechanical Analysis (DMA) | 45 |
| 3.4.3.3 | Dilatometer | 45 |
| 3.4.4 | Morphology properties | 46 |
| 3.4.4.1 | Scanning Electron Microscopy (SEM) | 46 |
| CHAPTER 4 : RESULT AND DISCUSSION | | |
| 4.1 | Material Characterization | 46 |
| 4.1.1 | Fourier Transmission Infra Red (FTIR) analysis for UM and TM particles | 47 |
| 4.1.2 | X-Ray Diffraction (XRD) | 49 |
| 4.2 | Mechanical properties | 51 |
| 4.2.1 | Flexural Modulus of UM and TM composites | 51 |
| 4.2.2 | Flexural strength of UM and TM composites | 53 |
| 4.2.2.1 | Mechanism of failure of muscovite composite | 57 |
| 4.2.3 | Fracture toughness of UM and TM composites | 58 |
| 4.3 | Thermal properties | 59 |
| 4.3.1 | Thermal stability for UM and TM composites | 59 |
| 4.3.1.1 | Comparison of thermal stability between UM and TM composites | 63 |
| 4.3.2 | Coefficient of Thermal Expansion (CTE) of UM and TM composites | 64 |
| 4.3.2.3 | Comparison of CTE value for UM and TM composites | 67 |
| 4.3.3 | Thermomechanical properties of UM and TM composites | 68 |
| 4.4 | Material Characterization | 74 |
| 4.4.1 | Size and geometry of alumina | 74 |

| | | |
|-----|---|-----|
| | particles | |
| | 4.4.2 Fourier Transmission Infra Red (FTIR) analysis for UTAL and TAL particles | 75 |
| 4.5 | Mechanical properties | 78 |
| | 4.5.1 Flexural modulus of UTAL and TAL composites | 78 |
| | 4.5.2 Flexural strength of UTAL and TAL composites | 80 |
| | 4.5.3 Fracture Toughness of UTAL and TAL composites | 85 |
| 4.6 | Thermal Properties | 87 |
| | 4.6.1 Thermal stability for UTAL and TAL composites | 87 |
| | 4.6.1.3 Comparison of thermal stability of UTAL and TAL composite | 90 |
| | 4.6.2 Coefficient of thermal expansion (CTE) for UTAL and TAL composites | 91 |
| | 4.6.2.3 Comparison of CTE performance between UTAL and TAL composites | 94 |
| | 4.6.4 Thermomechanical analysis for UTAL and TAL composites | 95 |
| | CHAPTER 5: CONCLUSION AND SUGGESTION FOR FUTURE WORKS | 102 |
| | REFERENCE | 105 |
| | APPENDIX | 114 |

LIST OF TABLES

| | Pages |
|---|-------|
| 2.1 Ceramic materials for substrate | 9 |
| 2.2 Substrate board material properties | 11 |
| 3.1 The properties of Lindoxy 190 | 33 |
| 3.2 The properties of fillers | 35 |
| 3.3 Properties of ethanol | 36 |
| 3.4 Properties of octadecyl trimethylammonium bromide | 36 |
| 3.5 Properties of (3-Aminopropyl) triethylsilane coupling agent | 37 |
| 3.6 Properties of hydrochloric acid | 37 |
| 3.7 The abbreviation names for alumina and mica composites | 39 |
| 4.1 Description of typical peaks recorded using FTIR for treated alumina particles. | 76 |
| 4.2 Comparison of Tg value between UTAL and TAL composite | 101 |

LIST OF FIGURE

| | | Pages |
|-----|--|-------|
| 1.1 | Schematic of package in reliability stress illustrating CTE mismatch a) Illustration of flip chip packaging b) cooling by relative humidity c) heating by temperature will cause warpage and thermo mechanical stresses in package | 2 |
| 2.1 | A diagram of packaging materials with consist zeroth, first and second levels packaging (Tummala, 2005) | 7 |
| 2.2 | A schematic of flip chip packaging | 7 |
| 2.3 | Various epoxy monomer a) diglycidyl ether bisphenol A, b) cycloaliphatic epoxy, c) tetraglycidyl diaminodiphenyl methane d) epoxy novolac | 12 |
| 2.4 | The types of acid anhydride a) hexahydrophthalic anhydride, b) phthalic anhydride, c) mellithic acid anhydride and d) nethyl endomethylene tetrahydrophthalic anhydride | 15 |
| 2.5 | Curing mechanism of epoxy monomer with acid anhydride using tertiary amines as catalyst | 16 |
| 2.6 | A diagram cross section of mica structure | 18 |
| 2.7 | The reactions for hydrolysis of alkoxysilanes and bond formation a) hydrolysis of alkoxysilanes and b) bonding to an inorganic surface | 23 |

| | | |
|-----|--|----|
| 2.8 | Types of organic structure with alkylammonium chain were attached to layered silicates (Le Baron, 1999) | 29 |
| 2.9 | Types of polymer layered silicates composites a) conventional composites, b) intercalated nanocomposites, c) Flocculated composites and d) Exfoliated composites | 31 |
| 3.1 | Chemical structure of 3,4-epoxy cyclohexyl methyl-3,4-epoxy cyclohexyl carboxylate | 34 |
| 3.2 | Chemical structure of methyl-5-norbornene-2,3-dicarboxylic anhydride | 35 |
| 3.3 | Chemical structure of aluminum oxide | 36 |
| 3.4 | Chemical structure of muscovite | 36 |
| 3.5 | Chemical Structure of Octadecyl trimethyl ammonium bromide | 37 |
| 3.6 | Chemical structure of (3-Aminopropyl) triethylsilane coupling agent | 38 |
| 3.7 | Schematic of fracture toughness specimen | 44 |
| 4.1 | FTIR transmission spectrum of muscovite with and without ion exchange treatment | 48 |
| 4.2 | The mechanism of ion exchange treatment of muscovite using alkyl chain | 49 |

(octadecyltrimethylammonium bromide)

| | | |
|------|---|----|
| 4.3 | XRD diffractogram of muscovite and treated muscovite particles | 50 |
| 4.4 | A diagram of an idealized mica structure a) before and b) after ion exchange treatment | 51 |
| 4.5 | Variation of flexural modulus with filler content for treated and untreated muscovite filled epoxy composite | 53 |
| 4.6 | Variation of flexural strength with muscovite content (wt%) for UM and TM composites | 55 |
| 4.7 | The morphology of a) untreated muscovite and b) treated muscovite at 30wt% filler content. | 56 |
| 4.8 | Schematic representation of crack initiation and propagation in muscovite filled epoxy composite under flexural loading | 57 |
| 4.9 | Variation of fracture toughness for treated (TM) and untreated (UM) composites at 40wt% filler content. | 58 |
| 4.10 | Summary of TGA curves of neat epoxy and UM composites filled at 10wt%, 20wt%, 30wt% and 40wt% muscovite contents | 61 |
| 4.11 | Summary of TGA curves of neat epoxy and TM composites filled at 10wt%, 20wt%, 30wt% and 40wt% muscovite contents | 62 |

| | | |
|------|---|----|
| 4.12 | Comparison of thermal stability between UM and TM at 40wt% filler contents | 64 |
| 4.13 | Variation of CTE values; before T _g and after T _g of UM composite at different filler loading | 65 |
| 4.14 | Variation of CTE values; before T _g and after T _g of TM composite at different filler loading | 67 |
| 4.15 | Variation of CTE values with filler loading for UM and TM recorded before T _g | 68 |
| 4.16 | Variation of storage modulus with temperature for UM at various filler loading | 70 |
| 4.17 | Variation of loss modulus with temperature for UM at various filler loading | 71 |
| 4.18 | Variation of storage modulus with temperature for TM at various filler loading | 72 |
| 4.19 | Variation of loss modulus with temperature for UM at various filler loading | 73 |
| 4.20 | Micrograph of the shape and geometry of alumina particles under 35,000 magnification. | 74 |
| 4.21 | FTIR spectrum of (a) untreated and (b) treated alumina particles with the part of the region i, ii and iii | 75 |

| | | |
|------|---|----|
| 4.22 | Typical peaks corresponding to i) OH-stretching and methylene asymmetric C-H bonding, ii) C=C stretching and N-H bending vibration and iii) methyl symmetrical C-H bending and Si-O stretching of untreated (a) and treated alumina (b) particles | 76 |
| 4.23 | Proposed chemical reaction between alumina particles and silane coupling agent with ethanol as diluent | 78 |
| 4.24 | Variation of flexural modulus of the UTAL and TAL composites as a function of the alumina content in wt% | 79 |
| 4.25 | Variation of flexural strength of the UTAL and TAL composites as a function of the alumina content in wt% | 81 |
| 4.26 | Series of FESEM micrographs of flexural fractured specimen corresponding to: (a) untreated and (b) treated alumina composites at 50wt% of alumina contents | 83 |
| 4.27 | Schematic representation of particle-matrix debonding in polymer matrix composites | 85 |
| 4.28 | Variation of fracture toughness (K_{IC}) with alumina loading of UTAL and TAL composites | 87 |
| 4.29 | Summary of TGA curves of neat epoxy and UTAL composite filled at 10wt%, 20wt%, 30wt% and 40wt% and 50wt% alumina content | 88 |

| | | |
|------|---|-----|
| 4.30 | Summary of TGA curves of neat epoxy and TAL composite filled at 10wt%, 20wt%, 30wt%, 40wt% and 50wt% alumina content | 89 |
| 4.31 | Comparison of thermal stability between neat epoxy, UTAL and TAL composites at 50wt% alumina loading | 91 |
| 4.32 | Variation of CTE values; before Tg and after Tg of UTAL composite at different filler loading | 92 |
| 4.33 | Variation of CTE values; before Tg and after Tg of TAL composite at different filler loading | 93 |
| 4.34 | Comparison of the effect of surface treatment with untreated alumina in coefficient thermal expansion at 50wt% filler loading | 95 |
| 4.35 | Variation of storage modulus with temperature for UTAL at various filler loading | 97 |
| 4.36 | Variation of loss modulus with temperature for UTAL at various filler loading | 98 |
| 4.37 | Variation of storage modulus with temperature for TAL at various filler loading | 100 |
| 4.38 | Variation of loss modulus with temperature for TAL at various filler loading | 101 |

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PENILAIAN ALUMINA DAN MUSKOVIT SEBAGAI PENGISI UNTUK BAHAN SUBSTRAT EPOKSI

ABSTRAK

Kajian melaporkan tentang penyediaan dan sifat-sifat komposit epoksi yang terisi pelbagai komposisi pengisi menggunakan kaedah pengacuanan. Dua jenis pengisi digunakan iaitu muskovit dan alumina. Rawatan pada permukaan pengisi-pengisi dilakukan untuk meningkatkan daya kelekatan permukaannya dan penyerakannya di dalam matrik epoksi. Pengisi-pengisi berjaya dirawat berdasarkan pencirian Perubahan Gelombang Infra Merah (FTIR). Kesan rawatan dan komposisi pengisi telah dikaji melalui sifat mekanikal komposit. Didapati kekuatan dan modulus regangan meningkat pada semua komposisi kedua-dua jenis pengisi. Modulus regangan meningkat daripada 3GPa (epoksi kosong) kepada 7GPa (40wt% pengisi) bagi komposit muskovit dengan modulus regangan yang diperlukan ialah 15GPa. Komposit muskovit dengan rawatan penukaran ion memberikan sifat-sifat terma yang lebih baik berbanding dengan komposit muskovit tanpa rawatan. Angkali haba pengembangan (CTE) telah berjaya diturunkan dari 69.4 ppm/°C (epoksi kosong) kepada 32 ppm/°C (40wt% pengisi) dengan nilai CTE yang dikehendaki ialah 16-20ppm/°C. Komposit epoksi terisi alumina dirawat menunjukkan nilai modulus regangan yang lebih tinggi iaitu 9GPa (50wt% pengisi) dan nilai CTE lebih rendah 22 ppm/°C berbanding epoksi kosong. Nilai CTE yang rendah diperlukan untuk mengurangkan tekanan dalaman dan rekahan pada substrat.

ASSESSMENT OF ALUMINA AND MUSCOVITE AS FILLERS FOR EPOXY

SUBSTRATE MATERIAL

ABSTRACT

The research reports the preparation and performance of particulate filled epoxy composites at various filler loading using casting method. Two types of fillers were used in this study; muscovite and alumina. Surface treatments were carried out to muscovite and alumina particles in order to improve the interfacial adhesion and dispersion in epoxy matrix. The treatments were characterized using Fourier Transmission Infra Red (FTIR), which indicate both particles have successfully treated. Mechanical properties were investigated in order to evaluate the effect of treatments and filler loading on the composites. It was found that the flexural strength and the flexural modulus increase over the range of filler loading investigated for both composites. In terms of flexural modulus, treated muscovite composite increase from 3GPa (neat epoxy) to 7.5GPa (40wt% treated muscovite) with targeted flexural modulus 15GPa. It was observed that muscovite composites with ion exchange treatment give better performance in terms of thermal properties as compared with untreated muscovite composites. In addition, the coefficient of thermal expansion (CTE) has successfully reduced from 69.4 ppm/°C (neat epoxy) to 32 ppm/°C (40wt% treated muscovite) with targetted CTE value of around 16-20ppm/°C. Apparently, the treated alumina exhibit high flexural modulus; 9GPa (50wt% treated alumina) and low CTE at as low as 22 ppm/°C compared with neat epoxy. The closer the CTE value of the substrate to the chips is preferable in order to minimize the internal stress and fatigue cracking.

CHAPTER 1

1.1 INTRODUCTION

The electronic industry is one of the fastest growing industries in the world today. As this market continues to grow, the demand for packaging processes in electronic packaging also increases. The packaging however requires a minimal cost and maximum efficiency. For many years, the ceramic substrate materials were used due to the low difference on coefficient of thermal expansion (CTE) between the silicon die (2-3 ppm/°C) and the substrate (15 – 18 ppm/°C). However, ceramic substrate materials are expensive and thus are undesirable in electronic application. In 1997, Intel proved that the same connection density and superior dielectric properties could be achieved by sequential build-up (SBU) laminate organic substrate (Veldevit, 2008). Therefore, organic substrates are preferable as reported by previous works (Veldevit, 2008, Petefish et al., 1998). In addition, the polymer composites are typically favored for their cost-effectiveness and design flexibility, while they can meet the processing and reliability requirement (Fan et al., 2004).

Many of the most critical reliability attributes are related to silicon die size and packages construction. The CTE mismatch between the silicon die and the board induces plastic strain in the solder joint during operation resulting in lower fatigue life and eventually cause solder joint failure (Bank et al., 2005, Tummala et al., 2004). The factors that influenced the performance of the substrate materials properties such as layer count, substrate thickness and even the metallization pattern on individual layers, also affect the stress condition and therefore reliability. Stress condition also causes

package warpage or nonflatness of the substrate material. Usually warpage and delamination are the main problems due to the continuous thermal cycle exposure (He et al. 2000). Therefore, the substrate material has to possess high thermal reliability during service. The warpage and the delamination problems are partly associated with the coefficient thermal expansion (CTE) mismatch as mentioned before between the solder and the substrate coupled with low flexural rigidity of substrate (Wakharhar et al., 2005 , Sun et al., 2005), Figure 1.1.

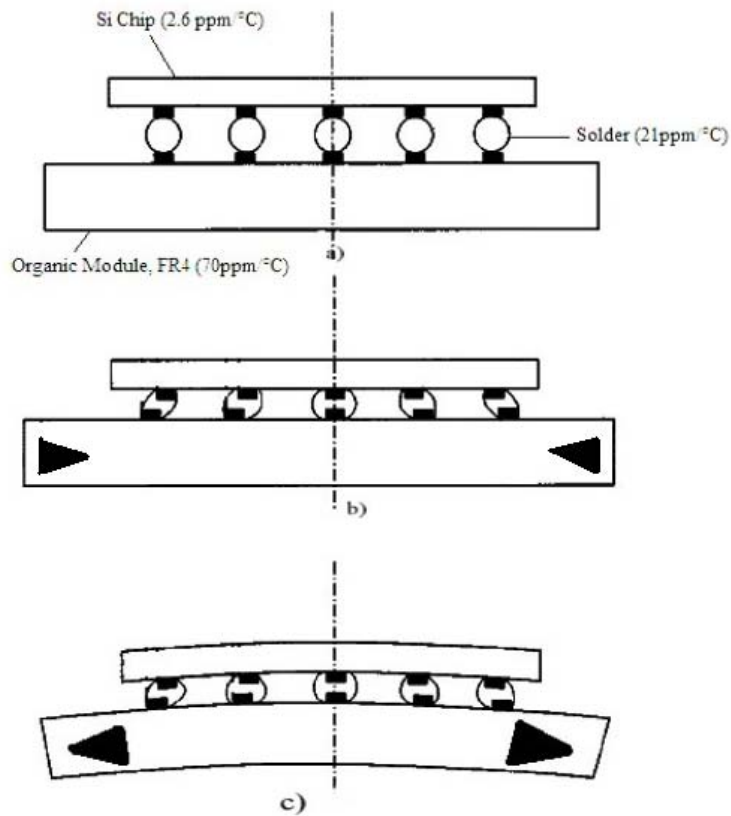


Figure 1.1: Schematic of package in reliability stress illustrating CTE mismatch a) Illustration of flip chip packaging b) cooling by relative humidity c) heating by temperature will cause warpage and thermo mechanical stresses in package.

1.2 Problem statement

As mentioned before, the major problem in electronic packaging is the CTE mismatch between the silicon die and organic substrate in zeroth level package. The mismatch usually resulted in warpage and delamination of the organic substrate during thermal cycle. In addition, after the thermal cycle, the substrate will not be flat enough due to the rigidity of the substrate. To solve these problems, the CTE must be reduced and at the same time improved the rigidity of the substrate in order to avoid the failure in the package. Hence, low CTE fillers and high rigidity were chosen. With those requirements as stated above, in this study was decided to choose alumina and muscovite as fillers. Alumina is rigid particles with modulus $>350\text{GPa}$ and good in thermal properties. While muscovite has platelet shape and expected will given better performance in mechanical properties. In addition, both fillers have low CTE ($<6\text{ppm}/^\circ\text{C}$).

1.3 Objective of the study

There are a few objectives in this research:

1. To investigate the various fillers like alumina and muscovite filled epoxy composites in terms of mechanical and thermal properties.
2. To study the effect of silane coupling agent on the properties of alumina filled epoxy composite.
3. To study the effect of ion exchange treatment in muscovite filled epoxy composite.
4. To improve the rigidity of alumina and muscovite filled epoxy composites and to reduce the CTE mismatch.

1.4 Scope of research

To solve the warpage and CTE mismatch, underfills are applied in packaging industry to improve the reliability. However, they tremendously increase the assembly costs and assembly complexity in processing [Veldevit, 2008, Tummala et al., 2004]. In order to attain the required reliability without underfill, the CTE of the substrate material has to match exactly with the silicon die and high modulus. The substrate of most rigid boards is made from FR-4 epoxy resin impregnated fiberglass cloth with 20GPa in modulus with CTE value between 16-20 ppm/°C [Blackwell, 2000]. However, FR-4 have the limitation which is it will not be flat enough to meet the requirements during thermal cycle. Therefore, particulate fillers in epoxy resin are applied in order to obtain the required properties and hence improved the warp and reliability of the package.

In this research, particulate fillers such as alumina and muscovite with layered silicates structure was selected in order to study the performance of the particulate in thermal and mechanicals properties. Beside that, surface treatment was done using silane coupling agent on the alumina surface. The effect of the surface treatment will be investigate. Meanwhile, for muscovite filler, ion exchange treatment was carried out. There have been several works on ion exchange treatment for montmorillonite (MMT) and a few studied was reported for muscovite [Agag et al., 2007]. In this study , muscovite are selected to done ion exchange treatment and the properties will be investigate.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of electronic packaging

In electronic packaging, the effectiveness of electrical function such as the reliability and cost of the system, not only depends on the electrical design but also by the packaging materials. According to Pecht et al., (1999) electronic packaging refers to the packaging of integrated circuit (IC) chips (die), their interconnections for signal and power transmission and heat dissipation.

In package materials, there are designed to enable the electrical and thermal performance requirement such as provide thermal paths and as electrical conductor or insulator. In addition, the package materials must provide high-reliability performance in order to keep pace with silicon and package technology advances and to protect circuit from environmental factors such as moisture, hostile chemicals etc (Wakharhar et al., 2005).

In order to classify materials in the electronic packaging, these packaging materials are separated in four levels of packaging such as chip, components, printed wired board and assembly level packaging that are referred as the zeroth, first, second and third level packaging as shown in Figure 2.1. The details about these levels are summarized as below:

a) Zeroth level packaging

This level focuses on semiconductor die materials, die attach materials and substrates.

b) First level packaging

Also known as, component level packaging is designed to enable interconnection between the devices and packages while providing the protection for the device against mechanical stress and chemical attack.

c) Second level packaging

Another name for this is Printed Wired Board (PWB). A typical PWB provides good in mechanical, thermal and electrical properties in an electronic system. In terms of mechanical, it is provide support for the component and a thermal conduction path for the heat dissipated by components. While electrical provides an insulator for the conductors.

d) Third level packaging

This level includes the interconnections and hardware required to realize an electronic system after the PWB have been assembled. Required electrical interconnections are primarily achieved using backpanels, connectors and cable.

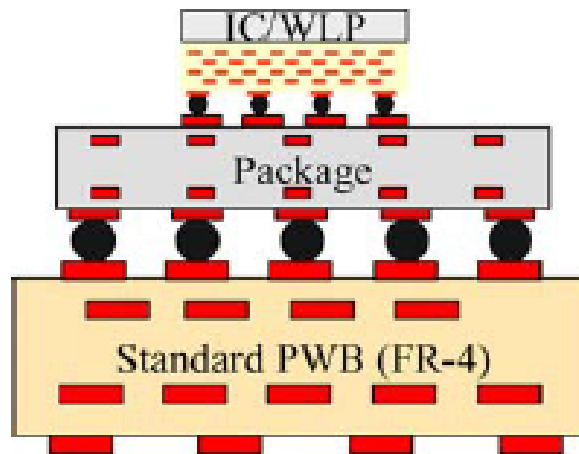


Figure 2.1: A diagram of packaging materials with consist zeroth, first and second levels packaging (Tummala et al., 2004)

2.1.1 Flip chip technology

In the traditional IC packaging, the silicon chip is wire-bonded to a leadframe and sealed by a ceramic substrate or plastic shell (He et al., 2000). Following Luo (2000), IC devices have moved to higher level and higher input/output (I/O) counts pushing the limit of the peripheral array of distributing the leads of an IC. Flip chip technology uses an area array of solder balls to provide a much longer I/O count over a given area of the IC. Figure 2.2 is an illustration of the flip chip package.

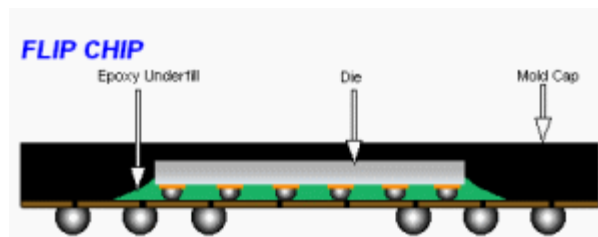


Figure 2.2: A schematic of flip chip packaging